EFFICACY OF CONCRETE ROOF TILES COMPOSITE USING CLAY AND RICE STRAW FIBRE AS HEAT INSULATION MATERIAL

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by

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LIST OF ABBREVIATIONS

CO	Control concrete
CPC	Climate Prediction Centre
CRS	Concrete Rice Straw
CRT	Concrete Roof Tile
CRTC	Concrete Roof Tile Composite
GJ	Gigajoule
GPa	Giga Pascal
IESVE	Integrated Environmental Solutions (Virtual Environment)
LEED	Leadership in Energy Environmental Design
MPa	Mega Pascal
NaOH	Sodium hydroxide
ONI	Oceanic Nino Index
PP	Polypropylene
RS	Rice straw
SiO^2	Silicon dioxide
SiO_4^{4-}	Orthosilicate
$[Si_4O_{10}]^{4-}$	Tetrahedral
XRD	X-ray Diffraction
XRF	X-ray Fluorescence
HTV	Hybrid Turbine Ventilator
HVAC	Heating, ventilation, and air conditioning

KECEKAPAN JUBIN BUMBUNG KONKRIT KOMPOSIT MENGGUNAKAN TANAH LIAT DAN GENTIAN JERAMI PADI SEBAGAI BAHAN PENEBAT HABA

ABSTRAK

Pada masa ini, jubin bumbung konkrit komposit (CRTC) dengan pelbagai peningkatan sifat sering digunakan sebagai penutup bumbung. Hal ini disebabkan oleh kelebihannya yang tahan sangat lama dan bertahan selama bertahun-tahun, dapat menahan angin kencang yang lebih baik daripada bahan lain, kos yang terlibat lebih rendah, lebih mudah diperolehi dan juga pengeluaran yang tinggi karana sangat mudah untuk dihasilkan. Penyelidikan ini tertumpu kepada sifat kejuruteraan, ketahanan dan sifat terma CRTC yang dihasilkan daripada pelbagai nisbah tanah liat dan serat jerami padi. Impak terhadap perbezaan panjang serat jerami padi juga telah diuji dalam kajian ini. Ciri-ciri jubin bumbung konkrit (CRT) juga telah diuji mengikut ASTM C1492 - 03 (2016) Spesifikasi piawaian jubin bumbung Konkrit dan kebolehmampuan CRT ini diuji dengan berdasarkan Kaedah Ujian Piawaian Aliran Mortar Hidraulik Simen (ASTM C1437). Prestasi terma seperti kekonduksian terma, kapasiti haba tertentu dan kelesapan haba telah diukur menggunakan Model Analisa Pemalar Haba Cakera Panas TPS 2500. Manakala, terma inframerah (imej IR) digunakan bagi mendedahkan perilaku terma yang berlaku keatas C10RS 1A berbanding sampel konkrit kawalan (CO). Prestasi terma dalaman diukur dengan menggunakan model rumah sebenar dan kaedah simulasi IESVE. Selepas itu, data dari kedua-dua kaedah ini dibandingkan dan digunakan untuk mendapatkan data sampel CO melalui simulasi IESVE. Hasil daripada keseluruhan ujian,

sampel C10RS 1A yang mempunyai campuran tanah liat dan gentian jerami padi mempunyai sifat kejuruteraan yang rendah tetapi ia bahan yang ringan, tahan hentakan dan kebolehtelapan air tinggi. Ia juga mempunyai kekonduksian terma yang rendah, kapasiti haba tertentu yang tinggi dan pembesaran haba yang rendah daripada sampel konkrit kawalan (CO), konkrit dengan campuran 10% tanah liat (C10) dan konkrit dengan campuran 1% jerami padi - 0.1cm -2.0cm (RS 1A). Purata ΔT C10 di dalam bangunan pada suhu maksimum adalah lebih rendah daripada suhu luar iaitu 3.68 ºC (semasa waktu paling panas) dan 0.65 ºC (semasa waktu paling redup). Jika dibandingkan dengan C10RS 1A, yang mempunyai purata ΔT iaitu 4.73 °C (semasa waktu paling panas) dan 1.70 °C (semasa waktu paling redup). Hasil ini menunjukkan konkrit dengan tanah liat dan serat jerami padi mempunyai kadar pemindahan haba yang lebih rendah dan menyerap haba matahari yang kurang daripada konkrit dengan tanah liat.

EFFICACY OF CONCRETE ROOF TILE COMPOSITE USING CLAY AND RICE STRAW FIBRE AS HEAT INSULATION MATERIAL

ABSTRACT

Currently, concrete roof tile composite (CRTC) with various properties improvement is frequently used for roof covering. This is mainly due to the advantages such as they are very durable and last for many years, can withstand high winds better than other materials, lower costs involved, more readily available and also production is high because it is easily manufactured. This research mainly focuses on the engineering, durability, and thermal properties of concrete roof tile (CRT) that were produced with various ratios of clay and rice straw fibre. The impacts of different lengths of rice straw fibre were also tested in this study. The CRT properties were tested followed ASTM C1492 - 03(2016) Standard Specification for Concrete Roof Tile and the workability of this CRT was tested according to Standard Test Method for Flow of Hydraulic Cement Mortar (ASTM C1437). Thermal performance like thermal conductivity, specific heat capacity and thermal diffusivity was measured using Hot Disk Thermal Constants Analyser Model TPS 2500. Besides that, the infrared thermography (IR image) was used to reveal the expected thermal behaviour of concrete with 10% clay and 1% rice straw (0.1 cm-2.0cm) C10RS 1A compared to control concrete (CO) sample. Indoor thermal performance was measured by using actual house model and IESVE simulation method. After that, the data from these two methods were compared and utilized in order to obtain the CO sample data via IESVE simulation. Results from the entire test proved that C10RS 1A sample with clay and rice straw has low engineering properties but it is lightweight, high shock resistant and high water resistance. It also

has lower thermal conductivity, higher specific heat capacity and lower thermal diffusivity than CO, concrete with 10% clay (C10) and concrete with 10% rice straw - 0.1cm – 2.0cm (RS 1A) samples. The mean of ΔT of C10 inside the building at maximum temperature was lower than outside temperatures which were 3.68 ºC (during hottest hours) and 0.65 ºC (during cloudiest t hours). Comparing to C10RS 1A, that has the mean of ΔT which were 4.73 °C (during hottest hours) and 1.70 °C (during cloudiest hours). This result shows concrete with clay and rice straw fibres has lower heat transfer rates and absorb less solar heat than concrete with clay.

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Concrete is the most generally used construction material in the world as a result of its versatile properties and economical price compared with the other materials. Concrete roof tile has long been in use as a roof covering for providing a stable and reliable engineering material. It provides certain benefits, remarkably solid product, can stand up to wind and storms, longer durability and more cost-effective than alternative building material that it competes with an excellent combination of its durability. Yet, the concrete roof tiles are fairly heavy and also the production is unconcerned about the amount of thermal efficiency. However, the usage of standard concrete roof tile has some limitations depending on the weather within the specific country.

Green certification programs like LEED, Energy Star, the U.S. Green Building Council and the Department of Energy Building Technology Program base their respective cool-roof credentials should have properties like an ability to reflect the sun (solar reflectance) and unleash absorbed heat (emissivity). The higher solar reflection factor and emissivity (on a scale from 0 to 1), the roof will be cooler.

Asian countries receive a large quantity of solar radiation, heat, high level of relative humidity, and long periods of sunny days throughout the year. Besides than that, the increased urbanization create development is simply too quick and densely at city space. It causes the rising temperatures and accrued the intensity of urban heat island (UHI) (Wong and Yu, 2011).

Insulation may be a key part of property building style. A properly insulated home reduces energy bills by maintaining cool throughout the hot time and turn lowers carbon emission affecting international temperature change. Referring to energy efficiency, committing to high amounts of insulation materials for residence is cheaper than buying expensive cooling technologies. It is really worth making the effort to search out the proper materials instead of changing the whole building design.

Insulation materials are widely used in roofs, walls and floors. Natural insulation products have various benefits over typical materials. They are low impact, made up of renewable, organic resources and have fully low embodied energy. They will be reused and recycled, and therefore are fully biodegradable. They are non-toxic, allergen-free that permits it to be safely handled and installed.

Therefore, a lot of analysis within the development of a new roof design and materials has been carried out. Engineers and scientists within the construction industry have proposed the use of cool roof, an upgraded and enhanced version of existing roof material. Much progress has been made within the development of roof style and material like using modified bitumen, single ply membrane, add a coat of cool, use a metal material, use an evaporative cooling system and different ways to create a cool roof.

Unfortunately, natural insulation materials are nearly 4 times pricier than standard materials, which might be a burden to builders, architects, and developers

(Gray, 2018). Apart from that, there are many problems that require confronted in dealing such as no long life cycle, need skilled labour, used high technology, and takes an extended time to provide additionally high maintenance cost. Even so, the environmental and health advantages of natural insulation materials decrease their prices, and growing consumer demand beside government regulation and rising oil costs can inevitably drive costs down. Natural insulation is usually an energy-efficient, healthy and sustainable choice for a better outdoor and indoor environment.

As the solution of this issue, the sustainable world's economic growth and people's life improvement greatly depend upon the utilization of different product within the design and construction, like sources of soil-based materials wastes natural material. They will be obtained at low price and low levels energy using local manpower and technology (Frybort et al., 2008). Concrete roof tile composites manufactured from cement, clay and lignocelluloses materials have several benefits such as higher strength, higher resistance to bio deterioration and light-weight, able to function as a thermal barrier, does not has formaldehyde emission originating from the binder and might be used as means of recycling wood residues.

On the other hand, the manufacture of ordinary Portland cement (OPC) could be extremely energy intensive and environmentally unfriendly method needed regarding 4GJ (gigajoule) of energy per ton of the finished product (Bahnsawy et al., 2015). Furthermore, the contribution of Portland cement production worldwide to the gas emission is calculable to be regarding 1.35 billion ton annually or about 7% of the entire gas emission to the earth atmosphere (Malhotra, 2002). Most cement kilns these days use coal and petroleum coke as primary fuels and, to a lesser extent, natural gas and fuel oil.

Cement manufacture causes environmental impacts at all stages of the process. These include emissions of airborne pollution within the variety of dust, gases, noise and vibration once in operation machinery and through blasting in quarries and damage to countryside from quarrying. Directly through the production of CO_2 (carbon dioxide) once calcium carbonate is heated, manufacturing lime and CO_2 and indirectly through the employment of energy, particularly the energy is sourced from fossil fuels. The cement industry produces regarding 5% of total global CO_2 emissions, of that 50% is from the chemical process, and 40% from burning fuel. The quantity of CO_2 emitted by the cement trade is almost 900kg of CO_2 for each ton of cement production (Bakhtyar, 2017).

In order to produce environmentally friendly concrete, Mehta (2002) suggested the utilization of fewer natural resources, less energy, and minimize CO_2 emissions. McCaffrey (2002) suggested that the amount of CO_2 emissions by cement industries will be reduced by decreasing the number of calcined material in cement, by decreasing the number of cement in concrete, and by decreasing the amount of buildings using cement.

Currently, the cement which will be used for building purpose is extremely costly and has gone beyond the reach of the low-income earners. These demand different sources of building materials. Examination of some different sources of soil-based materials establishes that there are several soil resources that are appropriate for construction. One among this soil-based is clay, wherever it is used as a cement replacement, will improve indoor temperature and also can reduce carbon emission. The previous study reveals, using clay brick will reduce the indoor temperature in 3% than mortar brick (Laaroussi et al., 2013). Besides, this fact also supported by Azhary et al. (2017), consequently the unfired clay bricks is a good insulating material because the decrease in the indoor temperature by an approximately 5.1°C during the hottest period in their study. Thomson et al. (2015) and they assert the most part to the exposed thermal mass that facilitate buffer the temperature and relative humidity of the indoor environment. There is also has a good material inclusion like mineral and organic aggregates to assist improve these thermal properties.

Clay is one of the oldest, contains a layer silicate mineral (called phyllosilicate) or different mineral that imparts plasticity and hardens upon drying or firing (Guggenheim and Martin, 1995). It might be referred to as a particle size in a soil or sediment of a diameter < 0.002 mm or 2 microns. Clay created from silica (SiO_2), alumina (Al_2O_3) and water (H_2O) plus significant concentrations of oxides of iron, alkali and alkaline earth. Figure 1.1 shows the pore size arrangement in clay.

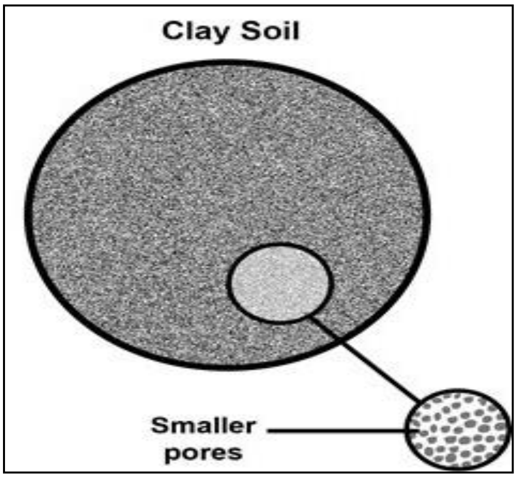

Figure 1.1 Pore size arrangements in clay (Manic Botanix. Com, 2016)

Chemical properties of clay show the clay contains high amounts of silica and alumina but included crystalline structure. Therefore, it doesn't possess amorphous pozzolanic activity and the strength is lower than fired clay. Nevertheless, by heating treatment, including calcining between 700 ^{0}C to 900 ^{0}C, this crystalline structure is ruined and quasi-amorphous structure is acquired. Clay contains physical and mechanical properties as example plasticity, shrinkage under heating and under air-drying, fineness of grain, colour once firing, solidity, lightweight, cohesion, and capacity of the surface to take decoration. Clay is the healthiest and additionally the foremost effective substance that one can use in order to construct sustainable building material in development. Clay is "good thermal mass", it is superb in retaining temperatures at steady level. Clay holds heat or cold, releasing it over a period of your time such as stone. Clay may be a living, breathing building material which in fact enhances the air around it, absorbing and releasing humidity comparatively fast. This leads to naturally controlled level of wetness and with it a healthier space environment is attained. Hence, designing and building with clay can contribute considerably to cut energy used.

Lignocelluloses agricultural by products are obtainable on a worldwide basis and regarded from renewable resources. Lignocelluloses actually are massive and cheap source for cellulose fibres. Agro-based bio-fibres possess the composition, properties, and structure that create them ideal for multiple uses namely composite, textile, pulp, and paper production. Moreover, bio-fibres also can be used to produce fuel, chemicals, enzymes, and food. According to Bouasker et al. (2014), no doubt, natural fibres, such as hemp, flax, cotton, jute, sisal, pineapple, cereal straw can be used in a variety of manners. Other researcher Patel et al. (2013) assert that groundnut husk, jute fibre, rice husk, rice straw, rice bale, saw dust, and coconut fibre and other fibrous material have been identified as most economically important wastes for building industry.

Rice straw is one of the extremely considerable agricultural trashes and one of the natural fibres. The National Food Security aims to increase the National Self Sufficiency Level (SSL) of domestic rice production from 70% to 85% by 2015. Malaysia needs to produce around 2.5 million metric tons of paddy annually (Rashid and Shah, 2013). That means, around the same volume of rice straw was produced in 2013. On the other hand, the rise in productivity and size of paddy areas, among different things, has resulted in enormous surplus of rice straw where the most cost-effective manner of getting rid of the residue is seen as burning the biomass within the paddy field that causes severe air pollution.

Rice straw contains a large quantity of fibre and features a nice potential to replace wood for the production of wide variety of composites. Producing composite materials from rice straw is probably going to contribute favourably to the disposal problem as well as to the overall CO_2 balance as a carbon sink. Converting rice straw into added products has conjointly the potential to boost the performance of agriculture sector. The better utilization of rice straw will also benefit farmers as an extra financial gain, which can be a crucial motivating factor in promoting an efficient harvesting, collection and management of rice straw. Additionally, the industry is additionally showing increased interest in the production of composite materials from agricultural residues due to the accuse shortage of forest resources.

Rice straw is classified as non-wood fibres; it is most useful as fibre for construction supplies, papers and also as animal feeds. Among the various agricultural straws, rice straw could be very interesting material as filler in biodegradable polymer composites, due to its good thermal stability, competitive specific mechanical properties, and availability, low cost and lightweight compared to different agricultural waste (Buzarovska et al., 2008). According the study by Mansour et al. (2007) found that the cement straw slabs can be used in new construction as well as in existing buildings to improve the thermal insulation and acoustic absorption. The rice straw can effortlessly be grinded into chips or particles, which are terribly the same wood particles or fibres. It is also are obtainable on a global basis and thought of renewable materials. Rice straw will be obtained at low cost and low levels energy using local manpower and technology (Frybort, et al., 2008).

The rice straw is primarily contained in carbohydrate components like hemicelluloses, cellulose, and lignin Hamid and Zain, (2014). Table 1.1 shows the percentage composition of rice straw. A study by Sjostrom (1993) showed that the chemical constituents of natural fibre like rice straw have specialised functions within the cell wall: cellulose forms strong and stiff crystalline regions, cellulose and hemicelluloses form semi-crystalline regions provide necessary flexibility whereas the amorphous regions of lignin give toughness and cohesion.

Table 1.1 Percentage compositions of rice straw (Chandel et al., 2009)

Components	Composition (%)
Cellulose	**37**
Hemicellulose	**24**
Lignin	**14**
Others	**25**

The mechanical properties of natural fibres rely on its cellulose type because each type of cellulose has unique cell geometry which determines the chemical compositions. Hemicelluloses chains to cellulose by hydrogen bonding and acts as cross-linking molecules between the cellulose microbial forming the cellulose-hemicellulose network, which could be considered to be the primary structural part of the fibre cell. Lignin is the compound that provides hardness to the fibres. Rice straw fibres could not reach great heights or rigidity without lignin. The rice straw resistance to microbial decomposition and enables this material appropriate as filler in building composite materials. As an alternative, high content of silica (up to 20%) signifies a further potential benefit relating to the flame retardant once utilised in building industry. From this perspective, rice straw has been examined as possible filler in numerous thermoplastic matrices. According Yang et al. (2004) have analysed polypropylene filled with rice straw composites. They documented that it did elevate mechanical properties, i.e. increased tensile modulus of the PP/rice straw composites with the increase of filler content.

The rice straw skin features a waxy structure which can result in poor cohesiveness with cement. It offers tensile strength, as rebar does in concrete. Rice straw is unique relative to additional cereal straws in being low in lignin and high in silica. Rice straw fibres strength of 3.5 grams/denier (450 MPa), elongation of 2.2%, and modulus of 200 grams/denier (26 GPa), similar to linen fibres (Reddy and Yang, 2006). The untreated rice straw has the best tensile strength than treated by water and NaOH (Morsy et al., 2011). NaOH treatment decreases the strength than water treatment attributable to the elimination of amorphous compounds like lignin and hemicellulose. Concrete filler rice straw clearly reduce the maximum hydration temperature attained (T) and increase the time of achieves the maximum temperature (t) as compared with standard concrete (Morsy et al., 2011). Within the same study, rice straw cementitious composite has a potential to be used in the production of a new lighter building material like brick due to its low density than other fibre. Water absorption and thickness swelling of straw cementitious composites were in the same range of wood cement composite material.

The use of rice straw is to produce composite concrete roof tiles that will improve thermal performance, enhances mechanical performance and physical properties like high strength, high durability, low density and less absorb water vapour. According Patel et al. (2013), a lot of building material products that have been produced from rice straw (see Figures 1.2, 1.3, 1.4 and 1.5) and it is very useful and sustainable building material.

Figure 1.2 Particle board (Yang et al., 2003)

Figure 1.3 Medium density fibre board (Alison Peng, 2016)

Figure 1.4 Straw board (Sokhansanj et al., 2004)

Figure 1.5 Cement bonded board (Mansour et al., 2007)

This particle board uses as a sound absorbing and for inner walls and improves the mechanical strength and water absorption of medium density fibre board uses as a wall celling and furniture. It also improves mechanical strength, water resistance, and cutting tools wear. Straw board uses as a wall and roofing and also improves the mechanical strength. All of these material function as improved thermal and sound absorbing, mechanical strength, water absorption, water resistance and durability.

1.2 Present Scenario in Malaysia

Considering that Malaysia is within the tropical region and consists of thirteen states and three Federal Territories. The country of Malaysia is in the Asia continent and the latitude and longitude for the country are 4.1936ºN, 103.7249ºE. Kuala Lumpur is the capital city, although the administrative seat of government moved in 1999 to the newly designed Federal Territory of Putrajaya.

Recently, Malaysia has more established increased urbanization as results of the fast growth of the urban population. The highest populated states in West (Peninsula) Malaysia based on population density are Kuala Lumpur, Pulau Pinang, and Putrajaya. In East (Borneo) Malaysia, the Federal Territory of Labuan has a substantially denser population than the much larger states of Sarawak (capital town Kuching) or Sabah (capital town Kota Kinabalu). The local is equatorial characterised by annual southeast (April to October) and northeast (October to February) monsoons. It is obvious that we are dealing with great deal of issues with regards to the sun and the wind. It is an unpleasant climate zone that receives a huge amount of solar radiation, high temperature, high level of relative humidity, and extended periods of sunny days throughout the year. Reported by Meteorological Stations, Petaling Jaya, Malaysia has maximum temperatures 34°C on 29 January 2015. For that reason, it is actually a lot of crucial to avoid solar radiation coming back from warming the building surfaces.

Table 1.2 Mean data for meteorological and environmental data for each site (Engel-Cox et al., 2012).

Site	Mean Daily Dry Bulb Temp. (°C)	Relative Humidity (%)	Average Wind Speed (m/s)	Global Solar Radiation (kWh(m^2d)
Subang (Kuala Lupur)	27.7	78.6	1.62	4.86
Kuantan	26.9	84.3	1.72	4.57
Sandakan	27.5	82.7	N/A	N/A
Kota Baharu	27.3	81.4	2.19	5.11
Bayan Lepas (Penang)	27.8	79.4	1.84	5.1
Sitiawan	27.2	83.8	1.03	4.62
Melaka	27.5	80.6	1.55	4.5
Senai (Johor Bahru)	N/A	N/A	1.31	3.73
Labuan	27.9	80.7	N/A	N/A
Kota Kinabalu	27.4	81	N/A	N/A
Bintulu	26.9	83.3	N/A	N/A
Miri	27.1	83.9	N/A	N/A
Sibu	26.6	84.3	N/A	N/A
Tawau	26.7	83	N/A	N/A
Kuching	26.4	85.1	1.32	4.19

As shown in Table 1.2, Labuan (27.9°C) and Bayan Lepas (27.8°C) had high Yearly Temperatures whereas Kuching (26.4°C) had the lowest (Engel-Cox Nair, and Ford, 2012). Bayan Lepas (5.10 kWh/(m^2d)) and Kota Baharu (5.11 kWh/(m^2d)), both in the northern part of Peninsular Malaysia, have the highest mean daily global solar radiation.

As a results of the phenomenon is high temperature, higher relative humidity, substantial periods of sunny days throughout the year and huge of solar radiation, resulting in the rising temperature and even more increased the intensity of urban heat island (UHI). UHI phenomenon has shown that the materials utilized in urban development possess higher absorptive heat capacities than the soil and vegetative land cover that they replace (Bingfeng and Pingjun, 2007; Santamouris et al., 2011; Taha, 1997). The "hard" land surfaces such as roads, bridges, parking lots, walkways, patios, roofs, and walls have a tendency to absorb solar radiation incident on them and radiate the energy at night; raising the surrounding temperature (Synnefa et al., 2006). However the intensity and magnitude of the urban heat island vary from city to another, it might be simply defined by the distinction in temperature measured between urban and rural areas, (Streutker, 2003). The urban heat island has been delineated as a pillow of heat air on top of the city (Sham, 1987). The foremost typical and recorded index of the urban heat island is the increase of air temperature (Valazquez-Lozada, 2002).

The reason of Malaysia is in tropical climatic locations, passive cooling is among the foremost difficult issues to overcome. The economical and the only choice for effective cooling are by introducing air conditioning. Having said that, such equipment involves has high initial and operational costs for installation, electricity and routine maintenance. Consequently, air conditioners are unexpected to be used extensively in building, particularly for low-income earners. Nevertheless, additional way which can be used to reduce indoor temperature is use of sustainable building material.

Cautious analysis of thermal properties of materials is made use of within the development of urban areas is used as a way to alleviate UHI. This will readjust outdoor heat environment transfer to the indoors. The principal properties governing the thermal performance of materials include reflectance and emittance (Wong and Yu, 2012). Additionally, thermal conductivity is likewise a part of important properties that need to be explored. Another study by (Santamouris et al., 2011) revealed that the material with high reflectance and emittance tend to lower surface temperatures thus transfer less heat to their surrounding though convection. This situation occurs due to exposure of direct sun light; the roof has a huge impact on the thermal performance of the whole building (Badrul Hisham et al., 2005). Suehrcke, et al. (2008) reported that about 1kw/m^2 of solar radiation falling on a roof surface during clear sky condition and from 20% to 95% of this solar radiation is absorbed. The roof surface absorbs and reflects solar radiation as well as it has effects on surface temperature and indoor temperature of the building.

1.3 Research Problem Statement

Due to its location, Malaysia receives the sun directly overhead almost all of the days through the year. According director general from the Meteorological Department, Datuk Che Gayah Ismail said in New Straits Times on 24 February 2015, that the weather from the end of March until mid-May is the monsoon season. She also said the current temperature is between 33 and 35 degrees Celsius. This season causes many areas to receive less rain over an extended period, leading to the hot and dry weather. The temperature turned out to be more terrible when the drastically increment of population at dense area like Kuala Lumpur, the national capital and most crowded city in Malaysia.

According to CIA World Factbook, 2014 Percentage urban population in Malaysia is 72.8% of total population in Malaysia in 2011. It really makes increased urbanization due to the rapid growth of the urban population. Increasing of housing demand will definitely have an impact on the cost of construction or development and thus the selling price of residential houses. These circumstances occurred because increasing of building material demand and create the source of material become scarcer.

Due to the increasing of development, it is can cause the rising temperatures within the urban area and urban heat islands. Kuala Lumpur is among urban heat island in Malaysia and is usually several degrees hotter compared towards the surrounding countryside on heat summer days, the air in a city is usually 6-8°F hotter than its surrounding areas. The impact from this situation, the solar heat is reflected and absorbed into the building at once reduce indoor thermal comfort.

The solar heat received into the building by conduction through various building components like the wall, roof, ceiling, floor, etc. Heat transfer also takes place from different surfaces by convection and radiation. Besides, solar radiation is transmitted through clear windows and is absorbed by the interior surfaces of the building. This situation can make decrease the thermal performance of a building. The thermal performance of a building depends on various factors namely design variables (geometrical dimensions of building components as an example walls, roof and windows, orientation, shading devices), material properties (density, specific heat, thermal conductivity, transmissivity), weather data (solar radiation, ambient temperature, wind speed, humidity); and also a building's usage data (internal gains due to occupants, lighting and equipment, air exchanges).

As a result of this, major heat gain of Malaysian houses derives from the roof. One of several major issues of Malaysian residential development would be the overheating of roof areas as results of inappropriate selection of roofing systems and materials. The unsuitable roofs which are used in the majority of new buildings do not resist the flow of heat in the hot day. This will cause the increase of the temperature during midday and also high indoor temperature compared to outdoor temperature at night.

Previous studies have shown that in Malaysian houses, the roof has a huge impact on the thermal performance of the whole building (Badrul Hisham, Samirah, Azni Zain, 2006; Nor Zaini, 2005). Once the heat gets into the rooftop space, the hot air heats up the inner structures and surfaces, and therefore the heat can likely be retained for most of the night. The excessive heat gained from the sun is radiated from the roof space to the occupants within the house through long wave radiation (Koenigsberger et al., 1980). According to previous studies, around 87% of heat transfer from the roof to occupant is through radiation process, whereby only around 13% of heat is transferred through conduction and convection (Cowan, 1973).

The above situation resulting in to the high cost of housing development, Malaysia has adopted several low-cost housing strategies, in an effort to compensate for growing housing demands. At present, the vast majority of housing units are used low cost and quality as a roof material, which is an adapted material from different climatic zones and countries with different types of natural resources. The use all of those substances as a building material can have a negative impact on the environment and people.

To overcome this problem the natural reinforcing materials can be obtained at low cost and low levels of energy using local manpower and technology and also low cost. Utilisation of natural fibres as a form of concrete enhancement is of particular interest to less developed regions where conventional construction materials are not readily available or are too expensive. Coconut and sisal-fibre reinforced concrete have been used for making roof tiles, corrugated sheets, pipes, silos and tanks (Agopyan, 1988).

Additionally, there are weaknesses in using the incorrect types of roof material like requires the high-density material, the high heat absorbent, fragile, easily mouldy, not long lasting, low resistance and strength, costly and also high maintenance cost. Concrete tiles weigh more than clay tiles, though the high density might not seem like a problem at first but the extra weight concrete roof tiles add onto the house can really cause problems with structural durability and over time the house might not be able to even support the weight of the roof anymore.

Common ones in use are: metal, asphalt, wood, ceramic, polymers and quite recently concrete has been explored as a suitable material and found to be useful. This concrete roof tile used cement as the major classical binder in construction industry is very expensive. This is because of phenomenal population growth and urbanization which have triggered high demand of cement for several construction purposes to meet up with the need to expand infrastructures (Otuoze, et.al 2012). Besides that, cement is boosting air pollution because have high CO_2 emission.

Therefore the need to connect the gap between demand and high price has warranted the need to investigate the use of cheaper alternative sources.

So, the inclusion of clay in the mix can reduce these used of cement in the concrete mix. It also can cut back the negative impact on the environment and humans contributed by cement used. Besides that, the usage of clay as additive in this concrete roof tile does not need a lot of skilled workers and technological equipment in the process.

One of the most abandoned materials in Malaysia is cellulose non-wood fibrous materials, like rice straw. The National Food Security aims to increase the National Self Sufficiency Level (SSL) of domestic rice production. Malaysia needs to produce around 2.5 million metric tons of paddy annually (Rashid and Shah, 2013). Which means that round the same volume of rice straw was produced in that year (John, 2013). However, the increase in productivity and size of paddy areas, among other things, has led to a huge excess of rice straw where the most efficient manner of disposing of the residue is seen as burning the rice straw in the paddy field. As a result, it is boosting air pollution and serious human health issues due to the emission of carbon monoxide (Allam, et al., 2011). Rather than burning the rice straw, recycling it with a mix of cement forms a sustainable low cost building material, which additionally reduces atmospherically pollution (Allam et al., 2011). The reuse of abandoned building materials avoids the waste of materials and the environmental problems caused by combustion which is in line with the green environmental protection theme advocated by China (Wang and Yan, 2018).

To avoid such a situation, in this study proposes the utilization of rice straw as a lignocelluloses material to improve and produce concrete roof tile composites as method to positively impact indoor conditions of Malaysia and also the resource poor countries of the developing world. Additionally to those advantages, the rice straw might acts as a thermal insulation material for the unpleasant Malaysian weather. Also, the use of thermal insulation helps to reduce energy costs, while creating pleasant indoor temperatures.

This concrete roof tile composite produce can act as a passive cooling material that can improve indoor thermal quality and also can enhance the mechanical and physical properties such as density, durability, heat absorption, water absorption, strength, and others.

1.4 Research Questions

i. What is the satisfactory of clay and rice straw ratio for concrete roof tile composite?

i. What the physical and mechanical properties of concrete roof tile with clay and rice straw as additional materials?

ii. How the thermal performance of concrete roof tile composite

iii. How to get thermal performance of actual house model data used the simulation by IESVE software.

1.5 Research Aims and Objectives

This study is designed to develop the performance of concrete roof tiles and allow this material suitable for low-cost housing applications. After identifying the main factors that contribute to the inferior properties of concrete roof tile, this study proposes a material for enhancing concrete roof tile physical, mechanical and also thermal performance.

The proposed method involves the following steps to improve the concrete roof tile mix: The first phase involves enhancing the properties clay before incorporating into the concrete roof tile mix. In this process, the raw clay was filtered the impurities and dirt.

The second phase involves modifying the concrete roof tile mix by the inclusion of fibres. In this study, rice straw fibre was used at various lengths and volume fractions to help modify and improve the properties of concrete roof tile.

The third phase is employs a suitable experimental programme to characterise the behaviour that leads to concrete roof tile composite as well as to fully understand the feasibility and effectiveness of the modification in enhancing concrete roof tile composite in physical, mechanical, and thermal performance.

The objectives of this study are as follows:

ii. To determine the recommended ratio of clay and rice straw in producing a newly concrete roof tile composite,

iii. To examine the physical and mechanical properties of concrete roof tile with clay and rice straw as additional materials,

iv. To evaluate thermal performance of the concrete roof tile composite in order to reduce heat transfer into the building
v. To examine thermal performance of actual house model and simulate data by using IESVE software.

1.6 Scope and Limitation of the Research

The major scope and limitation of this research work is to produce a concrete roof tile composite, which is able to enhance indoor thermal performance due to low heat absorption and high solar reflection. The concrete roof tile composite was produced from clay that has been cleaned of impurities derived from Sayong, Kuala Kangsar, Perak. This clay was dried under the heat of sun and processed through various crushing stages and then sieved using vibrator sieve to obtain the required particle size. Another material is rice straw that was collected from the paddy fields at Kuala Kurau, Perak. This material is collected, washed with water, dried under a sun drying, cut off and sieved using a vibratory sieve to obtain the required size.

i. The first approach involves improving the properties of concrete roof tile composite by combining two different materials, cement and clay as a binder in a mortar. Unfired clay was used as additional material in a concrete mix with three different percentages at 10%, 20%, and 30% by weight of the total cement content. The effects of these materials on the concrete roof tile composite mechanical and physical properties are determined. Several tests were conducted to investigate these properties, such as a test for particle size distribution, absorption, density, impact value, flexural and compressive strength.

ii. The second stage involves modifying the concrete roof tile composite mix by the inclusion of rice straw fibres. In this study, short rice straw fibres were added to the appropriate volume fractions to help modify and improve the properties of concrete roof tile composite in the strength, thermal absorption, and density. The method and mix proportion of concrete roof tile were designed according to the Malaysia Standard 10D036R1 (2014). Accordingly, fourthly series of concrete mixes were designed and prepared depending on the volume fractions of the fibre content used. Three different lengths of rice straw at 0.1-2.0cm, 2.1-4.0cm and 4.1-6.0cm were tested in three different amounts of percentages at 1%, 1.5%, and 2%, according to the volume fractions concept. Unfired clay was used as additional material in a concrete mix with three different percentages at 10%, 20%, and 30% by weight of the total cement content.

iii. The assessment of the engineering properties of concrete roof tile composite after adding rice straw include determining the slump of fresh concrete mix, physical and mechanical strength of hardened concrete, namely, water absorption, density, drying shrinkage, compressive strength, flexural strength and impact resistance. The proportion of the concrete roof tiles mixture complied with ASTM C1492-03 (2016). It was based on constant effective water/cement ratio of 0.45-0.61 for all concrete roof tile mixtures, to achieve a target flow diameter range of 105-115mm and a compressive strength of

2,500 psi (17.2 MPa) on the 7 days. The experimental tests examined the mechanical, physical and thermal properties of the cube sample exposed to water and plate sample is curing in 40^0C of the room conditions were conducted for up to 300 days. The test is to investigate the impact behaviour of the concrete plate was conducted after the entire tested sample reached at the testing age of 28 days. Concrete porosity and microstructure test is not carried out in this study.

iv. The final aspect of the study involved the method used to measure thermal performance properties of four types of concrete roof tile where the first is a normal mix (cement and sand), second is normal mix with clay, third is normal mix with rice straw and lastly normal mix with clay and rice straw. Thermal properties of this four mix was conducted using Hot Disk Thermal Analyzer and essential values such as thermal conductivity, thermal diffusivity and specific heat capacity were recorded. Besides that, in this stage a model house was used to examine roof thermal performance and the best of concrete roof tile composite was installed as a roof covering. Thermocouple measurement tools are placed in a model house. The temperature difference between the interior and exterior roof surface was recorded. Besides that, AEMC 1950 Thermal Imaging Camera 80 x 80 with Bluetooth was used to automatically display the cool and the hot spot values at the minimum and maximum cursor position. It displayed point that fell in the same temperature range and the displayed colour blue, red, brown or yellow as defines the range and tolerance. Simulate data from field test data